LXI Addresses Structural Test

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Open architecture designs have been the choice for many military and commercial test systems since their introduction. They offer a solution that is open-hardware and open-software based, computer and operating system independent, and highly modular in nature.

The introduction of the local area network (LAN) eXtensions for Instrumentation (LXI) standard has added another platform alternative, incorporating all of the open architecture advantages of Ethernet while increasing the number of critical components necessary for true test and measurement compatibility. LXI offers a glimpse into the future of test-system interfaces that is particularly interesting to designers who wish to leverage open-platform architectures for distributed measurement applications.

Another less obvious advantage of this platform is apparent when focusing on the data acquisition application arena. Classic data acquisition applications typically have involved independent signal-conditioning subsystems to amplify and filter inputs from transducers before sending the signals to the digitization hardware. This complicated the test setup and ultimately increased system cost.

The distributed nature of an LXI-based data acquisition platform makes it easy to place an integrated instrument containing signal conditioning, excitation, and digitization hardware near the test article and supports communications with the various test components via standard hardware, interfaces, and protocols.

Open Architecture Significance

The advantages of adopting an open architecture test platform span both hardware and software, providing a wide range of choices not available to those locked into proprietary designs. An open hardware approach guarantees that a well-defined set of signal and interface characteristics has been adopted and that multiple vendors will provide support and products for the defined standard. All of this results in reduced cost, extended test-system life cycles, and commercial-off-the-shelf (COTS) product availability.

The LXI standard was designed with hardware independence in mind, largely accomplished by leveraging well-established industry standards. The LAN interface for LXI devices is based on IEEE 802.3, and it is intended to support current and future networks with 100Base-T or faster connections.

Utilizing this standard greatly reduces entry obstacles for instrumentation manufacturers thanks to many standard interface implementations that have been driven by the PC market. The very nature of this interface also makes it suitable for many distributed applications. Standard Category 5 (CAT-5) copper connections can reach 100 meters point-to-point, and fiber-optic implementations can span several kilometers without additional switches or routers.

Open software support also plays an important role in reducing development costs and ensuring life-cycle management. Software independence is built upon well-defined standards such as those seen in plug-and-play drivers and IVI. This is further extended into the application development environment, providing the freedom of choice to select the software environment best suited to specific needs.

All LXI-compliant instrumentation is required to furnish an IVI driver: IVI-C or IVI-COM. This provides the flexibility to choose the development environment best suited to the application. These drivers can be used in a number of application programming environments such as C/C++, MatLAB, Visual Basic, VEE, and LabVIEW/LabWindows CVI. It also is possible to port instrument functionality into non-

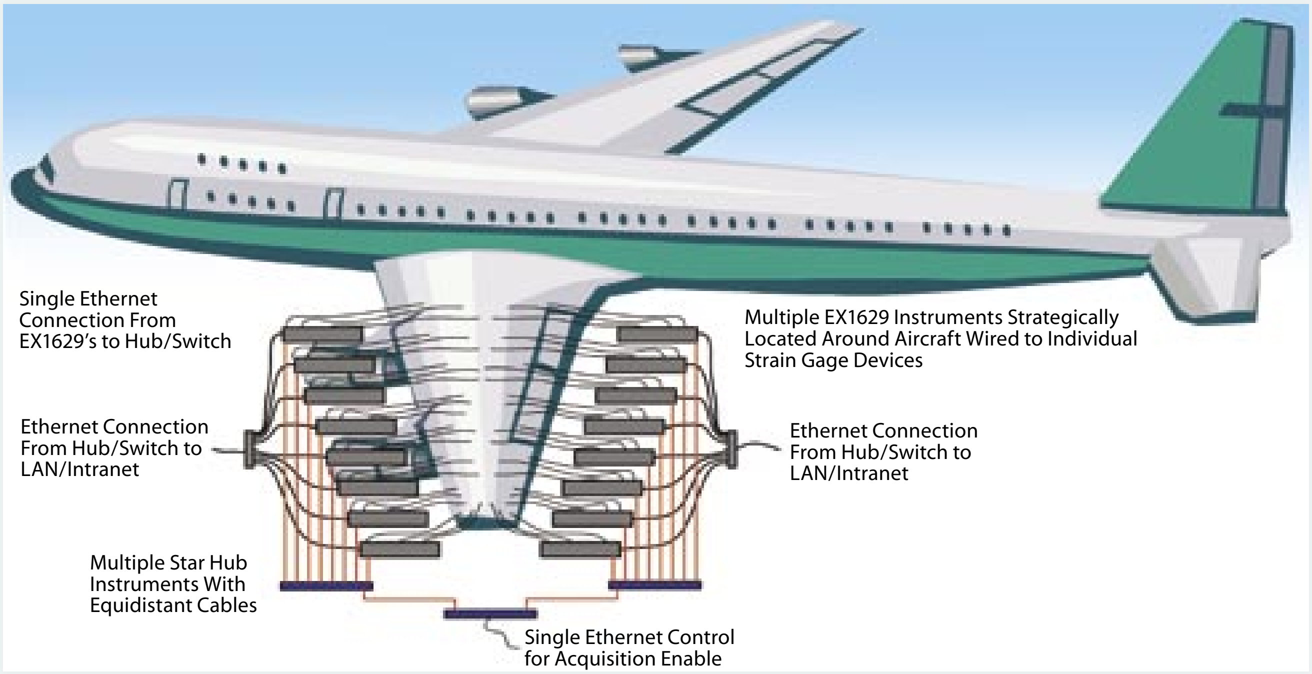

Figure 1. Aircraft Structural Test Setup

Windows based environments when source code is provided by the manufacturer.

Distributed Measurement Approach

Open hardware and software are fundamental requirements for any truly sustainable platform, but system designs using the LXI platform also provide an inherent benefit suitable for distributed data acquisition applications. Many traditional data acquisition implementations involve placing the instrumentation in a control room that may be located hundreds of feet from the article that is being tested. This distance presents numerous challenges including cable cost, maintenance, calibration, noise, and debugging.

Aircraft structural test applications illustrate this concept. Not only is the test performed some distance from the control room, but the sheer size of the test article also is a challenge. Fatigue testing on an aircraft wing may involve 5,000 to 6,000 channels of strain gage transducers that must be located at strategic points on the structure.

The cost of the cabling and installation will be significant; 5,000 strain gage channels would result in 40,000 connections (eight-wire configuration) that must be properly identified, cataloged, attached, and tested. Measurement errors due to cable loss and noise pickup also must be considered, and many installations have implemented proprietary calibration sequences and correction factors to compensate for these effects.

This effort results in a significant engineering investment. Maintenance and support also will be an issue because many tests of this nature span long time periods and are susceptible to typical fatigue issues and accidents. Fortunately, the effects from most of these issues are greatly reduced by placing the instrumentation as near to the test article as possible.

Distributed LXI-based instrumentation, such as VXI Technology's EX1629, a 48-channel high-performance remote strain measurement unit, can simplify the task. Each EX1629 can be placed near the test structure and connected to the test LAN using standard Ethernet cable and networking accessories (**Figure 1**). The simpler cabling and installation process decreases both setup time and cost.

Highly integrated instrumentation of this nature also improves accuracy by incorporating all signal conditioning and excitation sourcing within a single package. Separate analog excitation sources provide programmable bridge excitation voltages near the test article, and independent ADCs monitor the voltage applied to the strain gage. Extensive signal conditioning and filtering are integrated into the instrument along with comprehensive self-calibration to further improve system accuracies and reduce test setup times.

Once all of the LXI instruments are connected to the dedicated test LAN, a single Ethernet cable can be routed to the control room for data collection and control. While this approach simplifies installation and addresses several key areas of concern, a distributed approach still must address LAN use and access, synchronization, and trigger control, issues common to classic data acquisition applications and network installations.

Dedicated Test LAN

The affordability and ease of use of Ethernet network components are other reasons why LXI has been so openly accepted. Dedicated networks are inexpensive to install and provide the necessary isolation between corporate-wide network traffic and the test system. Additionally, with little effort, this network can be easily interfaced to the rest of the corporation or the World Wide Web.

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The low cost and ease of use of today's routers and hubs simplify the task of establishing a dedicated network. Standard CAT-5 cable is easy to route throughout test bays and around test articles, inexpensive to use, and available from many commercial sources. The familiar RJ-45 connector accommodates cable lengths that are easy to modify and customize.

Isolated instrumentation networks also eliminate many of the logistical issues that may arise when trying to conform to corporate network requirements. Security concerns can be addressed by not allowing physical access to outside network connections by installing a second Ethernet card, implementing a virtual private network (VPN), or physically disconnecting the network cable.

System synchronization and throughput also can be optimized using dedicated test networks. Today's generation of network switches has greatly reduced issues associated with traffic control and collisions common in earlier implementations, but independent test LANs can ensure the highest degree of performance.

LAN Synchronization

LAN synchronization incorporating IEEE 1588 Precision Time Protocol (PTP) provides the capability to time-align multiple devices in systems including clocks of different precision, resolution, and stability. PTP allows the synchronization of multiple LXI devices while eliminating the need for external cabling between devices. Submicrosecond accuracy can be achieved with minimal network and local clock computing resources and little administrative attention.

PTP can be implemented in several ways ranging from user-level software control to kernel-level driver modifications to hardware implementations using dedicated field programmable gate array (FPGA) devices. Gigabit Ethernet can provide synchronization times in the hundreds of nanosecond range, which are suitable for low- to medium-speed data acquisition rates common with certain static parameters such as thermocouple measurements. The highest level of precision is obtained when hardware implementations assist in the timestamping of incoming and outgoing network packets or frames.

Once multiple devices are synchronized using IEEE 1588 and a data capture sequence is initiated, individual samples can be time correlated with minimal effort. Many typical data acquisition applications require physical forces to be applied to the UUT. These forces can include tensile loading, temperature characterization, or simulated pressure variations. The measurement data then is time correlated with the excitation sources through the use of independent sample timestamps that are inherently available through the IEEE 1588 interface.

Hardware Triggering

The most accurate and deterministic synchronization mechanism between multiple devices involves the implementation of a hardware trigger interface. As a result of this requirement, the LXI standard defines a high-performance hardware trigger interface referred to as TriggerBus. TriggerBus can provide the link between all devices in the test system for triggering, synchronization, and clock signal distribution.

Deterministic trigger generation and propagation between multiple devices are accomplished with an eight-channel, multipoint low-voltage differential signal (LVDS) interface. This architecture permits individual lines to be configured as a source and/or receiver and supports external, time-based, or software-generated triggering as well as clock distribution.

Common topologies are supported including star, daisy-chain, and hybrid configurations, providing the flexibility to distribute the trigger lines as dictated by the application requirements. Flexibility is increased with the addition of a star hub. This device permits very tight trigger tolerances to be maintained throughout a large distribution network (**Figure 2**).

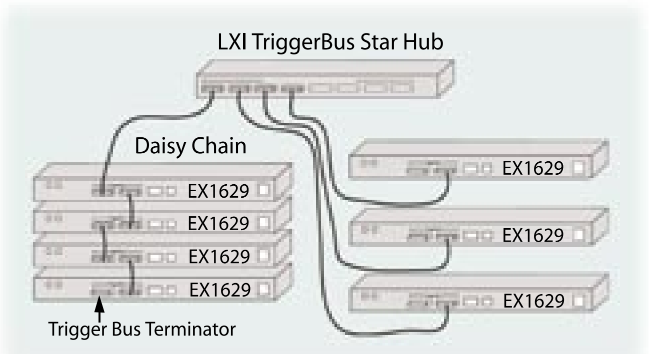

Figure 2. TriggerBus Star Distribution Configuration

The configuration in Figure 2 provides the capability to interconnect a very large number of instruments while preserving a high level of synchronization and timing performance that currently is not available with IEEE 1588. For applications requiring this level of triggering performance, the TriggerBus interface, standard on all Category A-compliant LXI devices, can be used to distribute system-wide clock, synchronization, and trigger signals.

Propagation delays between the various strain measurement instruments and the distribution hubs also can be minimized by using equidistant cables. This ensures extremely deterministic signal distribution throughout the entire system.

The TriggerBus also can automatically extend trigger and clock distribution signals to other platforms such as VXI with an LXI-VXI slot-zero control bridge. This provides a mechanism to link a VXI chassis with other LXI hardware.

The LXI-VXI slot-zero control bridge provides a direct extension of the eight VXI trigger lines to any external device, adding the capability to individually control specific instruments and switch devices within the VXI chassis. This type of flexibility supports integration of other instruments into a homogeneous open test environment, leveraging the strengths of each subsystem.

Summary

Many end users, integrators, and designers have been looking for the next logical step in the evolution of instrumentation interfaces, and it appears as if LXI has emerged as the clear choice. Obvious advantages such as high bandwidth, ease of connectivity, low cost, and readily available technology only scratch the surface of the possibilities that arise from the selection of Ethernet as the base technology.

Entire test methodologies are being transformed as more applications are considered under this new paradigm. The transition to distributed measurements is a prime example.

Large-scale structural, automotive and aircraft test-cell, and wind-tunnel test applications are just a few examples that will benefit from distributed Ethernet-based measurements thanks to the addition of key technologies such as IEEE 1588 and the hardware TriggerBus that ensure critical timing and synchronization requirements are met. Instruments with fully integrated signal conditioning now can be placed adjacent to test articles, eliminating miles of cabling and simplifying setup and maintenance. Performance and accuracies also will be improved as these new classes of instruments leverage functionality once considered only fitting for the laboratory.

About the Author

Jon N. Semancik is the corporate marketing and business development manager at VXI Technology and treasurer of the LXI Consortium. The U.S. Navy veteran has held engineering and project management positions on numerous programs in both the military and commercial sector. Mr. Semancik earned a B.S.E.E. from Fenn College of Engineering and an M.B.A. from the Weatherhead School of Management, Case Western Reserve University. VXI Technology, 2031 Main St., Irvine, CA 92614, 949-955-1894, e-mail: jsemancik@vxitech.com